THE EFFECT OF RELATIVE HUMIDITY ON CORONA ELECTROSTATIC POWDER COATING

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ABSTRACT

Cellulose, corn starch, maltodextrin, pork gelatin, potassium chloride, potato starch, rice starch, sodium chloride, soy protein, sucrose, and whey protein were vacuum dried and electrostatically charged by conveyor belt corona electrostatic coating system at 0 kV for nonelectrostatic, ±25 kV for electrostatic coating, at 15-80% relative humidity (RH). Powder flowability, resistivity, transfer efficiency and adhesion were measured. For salts, both improvement in transfer efficiency using electrostatics and powder resistivity decreased with increasing RH. Low powder resistivity causes low charge retention, which lowers transfer efficiency. For other powders, improvement in electrostatic transfer efficiency did not change significantly between 20% and 60% RH, but decreased at 80% RH. For these powders, resistivity is much higher than for salts. These powders can hold enough charge to provide improvement in transfer efficiency until 80% RH, when powder resistivity decreased and the moist air quenched charge significantly. For adhesion, the higher the powder resistivity, the greater the improvement for electrostatic coating. For proteins, both improvement in electrostatic adhesion and powder resistivity were high and decreased with increasing RH. For other powders, improvement in electrostatic adhesion was low and didn't change significantly with RH. There is no significant difference in adhesion between positive and negative corona coating for all powders at all tested RH. 20-60% RH is recommended for the industrial use of corona electrostatic coating.

INTRODUCTION

A flavored coating is applied to most snack foods and plays an important role in both the flavor and appearance of a snack. The snack food industry is constantly striving to obtain a competitive advantage by improving their flavor and appearance. From roll salter to pneumatic application, and tumble drum, many powder coating methods have been used to refine powder coating quality and efficiency. Electrostatic powder coating technology has been around for decades, and has been used in the food industry, especially in seasoning of snack foods. In corona electrostatic powder coating system, high voltage on the charging wire breaks down surrounding air and generates an ion rich region. When food powders transport through the ion rich region, they pick up charges quickly and land on the grounded food targets. Electrically charged food powder particles repel each other and form a uniform cloud to evenly coat a grounded food product. Electrostatic coating technology provides more uniform and efficient coating compared to traditional coating technologies.

Relative humidity (RH) has effect on corona discharge (Chen and Wang 2005). RH also affect powder resistivity and flowability, which have been discovered having influence on the electrostatic coating process (Sharma and others 2003; Stanford and DellaCorte 2002). The objective of this project is to determine whether the RH has influence on the transfer efficiency (TE) and adhesion of different food powders in corona electrostatic coating, and determine the best RH range for application of corona electrostatic coating in food industry.

MATERIALS AND METHODS

✷ Food powders: sucrose (Imperial sugar cane sugar: confectioners powdered, Imperial Savannah L. P., Sugar Land, TX), NaCl (Alberger 50 fine flake, Cargill Inc., Minneapolis, MN), KCl (A.C.S Reagent grade, Jenneile Enterprises, Cincinnati, OH), soy protein concentration (Protein Technologies International, Saint Louis, MO), whey protein concentration (WPI-90-regular, International Food Ingredients, Minneapolis, MN), corn starch (PURE-DENT B700, Grain Processing Corporation, Muscatine, IA), high amylase rice starch (Remy B7, A&B Ingredients, Fairfield, NJ), potato starch (unmodified food grade, AVEBE American Inc., Princeton, NJ), maltodextrin (MALTRIN M100, Grain Processing Corporation, Muscatine, IA), cellulose (Solka-floc, Fiber Sales & Development Corp., Urbana. OH), and hydrolyzed gelatin (Flavex 95, Arnehem Inc., Cranford, NJ).

✷Food powders dried overnight in vacuum oven

✷Electrostatic powder coating system (Terronics Development Corp., Elwood, IN, USA)
- 0 kV for nonelectrostatic coating
- ±25 kV for corona electrostatic coating

✷ Aluminum sheets were coated with food powders at 15%, 20%, 40% and 60% room R

✷ Powder resistivity, angle of repose (flowability), TE and adhesion were tested

RESULTS AND DISCUSSION

Transfer Efficiency

RH vs. Nonelectrostatic Transfer Efficiency

✷Transfer efficiency of salts decreased with increasing RH (Fig. 1).
- Powders with angle of repose lower than 45 are free-flowing (Table.1) (Peleg 1983).
- Angle of repose increase creases with increasing RH (Fig. 1).
- Higher angle of repose, lower flowability.
- Low flowability causes clumps of powder, which tend to roll off the target, resulting low transfer efficiency (Ricks and others 2002).

✷RH had no significant effect on transfer efficiency of proteins and carbohydrates .
- Powder with angle of repose higher than 45 are cohesive (Table.1) (Peleg 1983).
- Further decreases of flowability for already cohesive powder will not significantly affect TE.

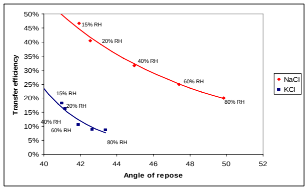

Fig.1 Transfer efficiency and flowability decreased with increasing RH for salts.

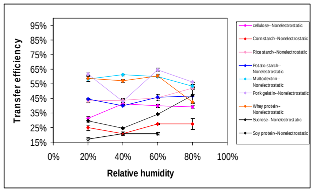

Fig.2 RH had no effect on nonelectrostatic transfer efficiency for carbohydrates and proteins.

RH vs. Improvement in Electrostatic Transfer Efficiency

✷ Improvement in TE decreased with increasing RH for salts (Fig.3).
- Increasing moisture in the air quenches charge (Pavlik and Skalny 1997).
- Powder resistivity decreased with increasing RH, resulting low charge retained on powder (Fig.7).

✷RH had no effect on improvement in TE for carbohydrates and proteins between 20 - 60% RH, but decreases at 80% (Fig.4).
- Powders with high resistivity can hold enough charge until 80% RH, when charge is significantly quenched by water in the air.

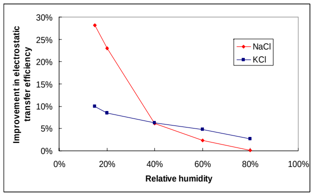

Fig.3 Improvement in electrostatic transfer efficiency decreased with increasing RH for salts.

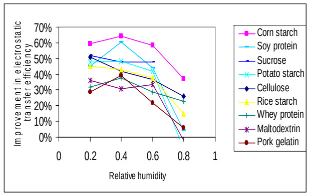

Fig.4 RH had no effect on the improvement in electrostatic transfer efficiency until 80% RH for proteins and carbohydrates.

Positive Electrostatic vs. Negative Electrostatic

✷ There was no significant difference between positive and negative electrostatic coating for all tested powders at all tested RH, except soy protein and pork gelatin.

✷ Positive electrostatic coating produced higher transfer efficiency than negative electrostatic coating.
- Soy protein and pork gelatin have high positive tribocharge value (Fig.5).
- Positive corona charged powders have more absolute charges on powder, which leads more powders to the targets, resulting high TE (Sumawi and Barringer, 2005).

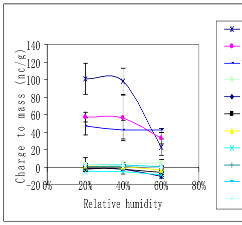

Fig.5 Tribocharge value of all food powders at 20-60% RH.

Powder	Angle of repose at 20% RH	Cohesiveness (Peleg 1983)
NaCl	**41**	**Free flowing**
KCl	**42**	**Free flowing**
Maltodextrin	45	Cohesive
Potato starch	48	Cohesive
Rice starch	48	Cohesive
Sucrose	50	Cohesive
Pork gelatin	53	Cohesive
Whey protein	54	Cohesive
Corn starch	55	Cohesive
Soy protein	56	Cohesive
Cellulose	64	Cohesive

Table.1 Angle of repose of all food powders at 20% RH.

Adhesion

RH vs. Nonelectrostatic Adhesion

✷ RH had no effect on adhesion of all food powders in nonelectrostatic coating, except adhesion of maltodextrin increases at 80% RH (Fig.6).
- Maltodextrin partially dissolved.
- Maltodextrin is the only powder dissolved after being stored in 80% RH condition.

RH vs. Improvement in Electrostatic Adhesion

✷ RH had no effect on the improvement in adhesion for carbohydrates and salts (Fig.8).
- Resistivity lower than 1*E+10 (Omh*m), the charge decay is rapid enough and the adhesion is so weak that the powder may not remain attached to the targets (Sims and others 2000) (Fig.7).

✷ Improvement in adhesion for proteins decreased with increasing RH (Fig.9).
- Soy protein, whey protein and pork gelatin have resistivity higher than 1*E+10 (Omh*m), and can retain enough charge (Sims and others 2000) (Fig.7).
- Resistivity decreased with increasing RH, resulting less electrostatic force.

Positive Electrostatic vs. Negative Electrostatic

✷ There was no significant difference in adhesion between positive and negative electrostatic coating for all tested powders at all tested RH.

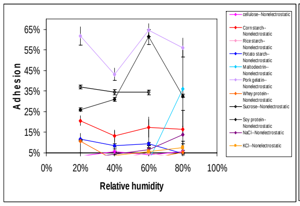

Fig.6 Effect of RH on nonelectrostatic adhesion.

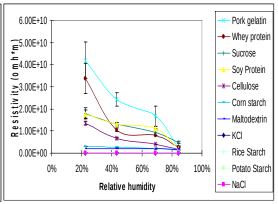

Fig.7 Resistivity of all powders at 20-80% RH.

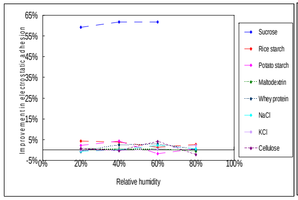

Fig.8 RH had no effect on improvement in electrostatic adhesion for carbohydrates and salts.

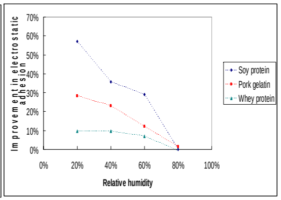

Fig.9 Improvement in electrostatic adhesion of proteins decreased with increasing RH.

CONCLUSIONS

✷ High RH decreases transfer efficiency improvement of salts in electrostatic coating, but not carbohydrates and proteins until 80% RH

✷ High RH decreases adhesion improvement of proteins in electrostatic coating, but not carbohydrates and salts.

✷ 20 - 60% RH is a good working RH range for food industry's application of corona electrostatic coating, providing best combination of transfer efficiency and adhesion.

✷ Environment RH needs to be controlled for electrostatic coating of salts and proteins, but not for carbohydrates.

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